GROWING KNOWLEDGE

Series content is coordinated by Dr. Jay Pscheidt, professor of botany and plant pathology at Oregon State University in Corvallis, Oregon.

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The smart greenhouse

OSU researchers look to repurpose and adapt high-tech trackers and sensors for plant production

BY LLOYD NACKLEY, CHET UDELL AND ALAN DENNIS

GREENHOUSES ARE CRITICAL for nearly all nursery operations. They enable greater control over the growing environment for plants, providing numerous advantages in the face of unpredictable weather and increasing droughts.

That's why many growers use them to produce high turn floriculture, seasonally protect less-hardy perennials, and propagate plant material.

Unfortunately, today's aging greenhouses often fail to take advantage of new sensing, tracking and data technologies. Such technologies could make greenhouse management more automated and efficient.

Many of us are familiar with the Internet of Things (IoT), which is the extension of the Internet beyond just computers, smart phones and TV sets. Everyday objects such as refrigerators, coffee makers, cars, and traffic lights can now collect data and not only communicate over the internet, but autonomously collaborate to optimize our daily lives.

Cisco Systems estimates that more than 250 "things" connect to the Internet each second, with 50 billion total devices communicating online.

In a world where shoes can keep track of how fast and far we run, Internet-enabled distributed sensors that can automate and optimize greenhouse infrastructure offer exciting potential. With this technology, temperature, relative humidity, lighting levels, CO_2 levels, air quality and more could be managed and controlled as efficiently as the smart thermostat in your home.

Overcoming the cost hurdle

Precision agriculture — the use of information technology to support farming — is a growing field. There are at least three major roadblocks standing in the way of this technology being adopted — lack of time, lack of capital, and lack of confidence.

The nursery business is a busy one. Between growing plants, filling orders, shipping trucks and getting ready for the next season, there's hardly enough time to rest, let alone keep up to date on the newest technological advancements.

Where some growers have the luxury and capital to renovate or construct new infrastructure with the latest technologies built in, most of Oregon's farms are sole proprietorships managed by


Manuel Lopez and Lars Larson programing the first generation sensor package at NWREC. PHOTO BY LLOYD NACKLEY

operators age 55 and older. Building new, state-of-the-art facilities is neither an option nor a priority for many of these small-to-midscale family businesses.

Commercial sensors can cost more than $200 per sensor, with additional costs for data-logging and wireless connectivity running more than $1,000 per location. Wireless sensor networks can easily cost more than $10,000 per greenhouse, which really adds up when extended over many acres and many greenhouses.

One alternative solution is to try an off-the-shelf IoT kit such as the popular Arduino, an open-source hardware and software company and user community. Unfortunately the learning curve can be fairly steep for these do-it-yourself (DIY) technologies. To use them effectively requires knowledge in programming and electronics, making them inaccessible for the average grower.

To address these roadblocks, the Nursery Production Lab (@NackleyLab on Twitter) has partnered with the Openly Published Environmental Sensing (OPEnS) Lab to develop an open-source, environmental sensing system that can be retrofitted into aging greenhouse infrastructures. This research is supported by a grant from the Oregon Department of Agriculture from state nursery license fees, as recommended by the Oregon Association of Nurseries Research Subcommittee.

By borrowing technologies from other electronic commu-

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Manuel Lopez and Lars Larson programing the first generation sensor package at NWREC. PHOTO BY LLOYD NACKLEY

OSU undergrads assembling the pieces on the 3D gantry system for the HyperSense. PHOTO BY ARIEL STROH

nities, the Oregon State University team is seeking to create low-cost sensors to enable growers to take advantage of powerful IoT sensing and automation technologies without the need to rebuild new structures from the ground up.

Sensors that travel

In 2018, the Nackley Lab kickstarted a project with two OPEnS lab students, Lars Larson and Manuel Lopez, to prototype, install, test, and validate a sensor package at OSU's North Willamette Research and Extension Center (NWREC). Larson and Lopez had been working on a sensing system called the HyperRail that was originally developed to analyze a forestry crop using hyperspectral imaging.

Nackley and the OPEnS Lab director, Professor Chet Udell, wanted to see if the rail system could be modified for use in a greenhouse. The project was called a HyperRail because it is a track that allows a sensor package to travel, as an automated train, above a crop in a linear pathway.

The HyperRail was designed to be a modular system in many aspects. The first is length; this system can be adjusted to any greenhouse length.

The next modular element is the carriage system. This system is built onto a piece of polycarbonate that is cut to size, with holes drilled to specific requirements for the motor. It can be a stand-alone frame or can be mounted to either tripods or a structure.

These students are emblematic of a growing community of open source inventors at OSU who are part of an emerging "maker movement." There are deep ties between the maker movement and open source technology often attributed to software development. Both are rooted in a sharing culture, with the belief that open collaboration creates greater insights and opportunities for all.

According to the National Academy of Engineering, "free and open-source hardware is changing the face of science, engineering, business, and law." The maker movement is an extension of the DIY culture where science, art, and the curiosity inherent in tinkering collide. This movement also aligns nicely with the land grant mission of OSU as a leading public research university.

Larson and Lopez gathered data from the HyperRail prototype at NWREC, and with their advisors, Nackley and Udell and with funding support from the OAN-ODA Nursery Research Program they developed a plan to expand the product into a system they call HyperSense. The greatest difference between the HyperSense system and the original HyperRail prototype is the HyperSense package will be deployed in a 3D track system to create a system that can be configured for a wide variety of sensing purposes.

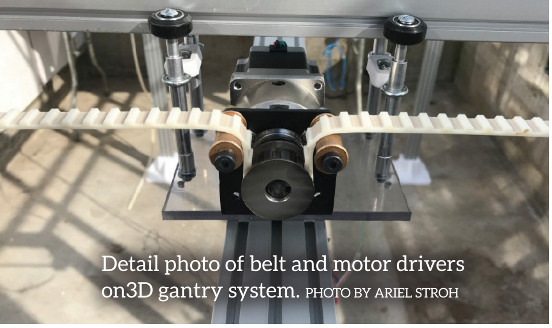
The HyperSense moves in three directions over a 25-meter rail on the x-axis continuously, two-meter on the y-axis, and one-meter on the z-axis, with the sensor package attached on the z-axis in a 3D-printed container. Nema 23 motors drive the sensor package along the rail with the use of a single belt system. The carriage can be programmed to visit a suite of locations to gather information from the on-board sensor package.

While the sensor package is in motion, it saves the data onto a web document called Spool. The OSU student team is also creating a website that will help make the data user-friendly and visualize the data into graphs and charts. Sensors implemented include CO_2 (K30 10,000ppm), temperature (Adafruit SHT31), relative humidity (Adafruit SHT31), luminosity (Adafruit TSL2591), and air quality (Nova SD011). There are plans to integrate multi and hyperspectral sensors, 3D imaging, RFID, and other technologies in the future.

Further testing

The HyperSense 1.0 will be tested and modified throughout the 2020 growing season at NWREC. When the team is satisfied that the package is robust for greenhouse conditions the plans will be freely shared on the OPEnS Lab website.

In addition to developing low-cost open-source technology solutions, this research collaboration is helping develop the pool of skilled laborers in Oregon, by provid-



Detail photo of belt and motor drivers on3D gantry system. PHOTO BY ARIEL STROH

ing research opportunities for horticulture students, as well as bringing-in computer science and engineering students who otherwise may not engage with Oregon greenhouse and nursery production systems.

Oregonians like Lopez became interested in creating electronic devices during robotics competitions through the MESA program (Mathematics, Engineering and Science Achievement) at Liberty High School in Hillsboro, never expected to be installing sensors in a greenhouse. None of the engineers on the OPEnS Lab team had any greenhouse experience for that matter. But that's one aspect the students like about working on these projects.

According to Lopez, "The open-source part of this connects everything. Each project that the OPEnS Lab collaborates on, including the HyperRail, is released under an open-source license." This means that all of the design files, computer code, bills of materials and instructions are freely accessible to anyone who wants to download them from their website at **www.open-sensing.org.**

Some community members who download and use OPEnS projects modify the designs or code and even send their improvements back to the lab so that others can benefit from them. It's a collaborative, iterative process.

"Many people tap into our projects at really high rates," Lopez says. "They work on it from there, and we work on our stuff from here."

Check in with the nursery team at NWREC this summer to see how the HyperSense team is growing together to provide science and engineering solutions that help sustain nursery production systems in Oregon.

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